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Electronics Program

Infrared Device Research

SEMIANNUAL TECHNICAL REPORT

(1 January-30 June 1962)

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Prepared by J. MUNUSHIAN

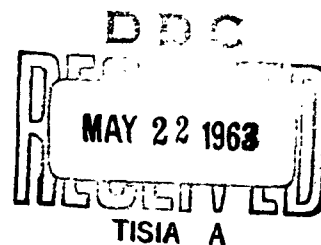
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ELECTRONICS PROGRAM •

Infrared Device Research

SEMIANNUAL TECHNICAL REPORT

(1 January - 30 June 1962)

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ABSTRACT

Investigation of gallium arsenide recombination radiation and cooling properties has been initiated. Work will soon commence on the evaluation and standardization of suitable standards for performance characterization of infrared image tubes. Capability for measurement and evaluation of infrared image tube characteristics is nearing completion.

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I. INTRODUCTION

Development of techniques for infrared energy detection using both point-source and image-forming devices and for generation of high-intensity infrared energy is of extreme importance to the military mission. The use of lead sulfide detectors and infrared image tubes in such varied applications as ballistic missile detection, night viewing, and horizon stabilization is well known. Recent discovery of high efficiency infrared energy generation (Ref. 1) in semiconductor junction diodes has created considerable interest and excitement because of the potential application of such devices in space communications and control.

Development of successful devices depends heavily upon the basic understanding of the properties of materials and the manner of their interaction with electromagnetic energy. Present detection devices are restricted in wavelength response, sensitivity, and reliability. Present energy-generation devices are limited in wavelength coverage, efficiency, and even in the basic understanding of the physical mechanisms involved.

To achieve improvement in the aforementioned areas of present limitation, it will be necessary to investigate the physics of infrared sensitive materials and to explore the development of new detection, image-forming, and energy conversion mechanisms.

II. DISCUSSION

A. GALLIUM ARSENIDE DEVICE

The recent discovery by Lincoln Laboratory scientists, that it is possible to generate an intense beam of infrared radiation by applying electric power to a gallium arsenide (semiconductor) diode, has attracted much interest. This

important discovery allows an entirely new portion of the electromagnetic spectrum to be used for line-of-sight communication. Some of the possible applications of this device include communications with re-entry bodies during blackout, megamile communications, docking operations, and collision-avoidance systems.

The radiation produced by the gallium arsenide device arises from an unexplained, high order of efficiency, recombination radiation. The radiation produced is 100 angstroms wide, centered at a wavelength of 8600 angstroms. When cooled to 77°K, the efficiency approaches 100 percent. The power density, generated per unit area, is comparable to that of the sun but generated over a much narrower spectrum.

Work on recombination radiation in semiconductor junctions has just started in our laboratory. Much of the effort has been devoted to the organization and development of basic laboratory facilities suitable for work on semiconductor devices. These facilities include dicing and lapping equipment, diffusion furnaces, and equipment such as Hall magnets and resistivity probes for the measurement of semiconductor characteristics. In addition, equipment such as spectrometers and monochromators, for the measurement of infrared recombination radiation, has been assembled and tested.

While diode fabrication and evaluation facilities have been under development, effort has also been expended on a literature search and some theoretical work. The general field of recombination radiation has been surveyed. The cooling (or refrigeration) aspects of recombination radiation have been investigated. Preliminary calculations indicate that this method of refrigeration may be useful in certain specialized forms of cooling such as infrared signal generator diode self-cooling, increasing black-body radiation, or as a miniature refrigerator requiring no compressor or heat exchanger.

Initial laboratory work has started on optical transmission of gallium arsenide wafers in which excess carriers are created by photoexcitation rather than by the Lincoln Laboratory techniques of diode excitation. In addition, silicon alloy devices have been examined for recombination radiation, but this radiation has not yet been observed. Gallium arsenide diodes will be made and the radiation from such devices will be investigated, when facilities for the fabrication thereof are completed.

B. INFRARED IMAGE TUBES

A program is underway to study and develop criteria and measurement methods for the characterization of the performance of infrared image tubes. There are presently no universally acceptable criteria. The major tube parameters being studied are: 1) sensitivity, 2) resolution, 3) dynamic response, 4) spectral response, 5) spurious response, 6) time of response, and 7) distortion.

Laboratory facilities are being developed to evaluate state-of-the-art infrared image tubes which use sensing layers of photoconductive and bolometric materials. These facilities include: 1) an electronic digital scanning system, 2) an all-reflective optical system, 3) controllable infrared sources, and 4) electron optical controls.

The electronic digital scanning system will provide variable picture frame rates and control the number of picture lines per frame. The resistance, capacitance, energy spreading, and uniformity characteristics of the sensing layer can be determined with this system. These parameters are important in the determination of tube resolution and response time.

The all-reflective optical system will image a high resolution picture on to the sensing layer of the image tube. This system will operate in the visible to far infrared range (.4 to 30 microns), at resolution values better than available in state-of-the-art image tubes. Provisions are included to cool the optics to liquid nitrogen temperature (77°K) in the event that energy from background radiation is a problem. With this optical system, resolution and spectral response measurements can be made for state-of-the-art infrared image tubes.

The controllable infrared sources will supply black-body energy at temperatures up to 1000°C . The accuracy of these sources is within 2°C up to 230°C and within 5°C above 230°C . This equipment will accurately control target intensity, allowing accurate sensitivity and dynamic range measurements. Specially fabricated infrared test patterns will be placed between the infrared source and optical system for resolution measurements.

The electron optical controls will provide the ability to change dynode, focusing, mesh, and acceleration voltages in the electron gun structures. The controls have the capability to vary voltages on the sensing layer and to record operating time for tube filaments. Control of the aforementioned voltages is necessary to optimize output video signal-to-noise ratio and beam-landing uniformity across the sensing layer.

The measurement system is nearly completed and actual measurements on tubes will commence in a few months. The experimental data derived from these laboratory facilities will be used to standardize measurement techniques and criteria for infrared image tubes. This effort will be coordinated with the work of the IRIS* Specialty Group on Image Sensing Devices and finalized standards will be set up in conjunction with this specialty group.

The problem of dynamic range in infrared vidicons has been studied; and a method, based on an extension of long wavelength response, has been developed to permit image tubes to handle increased dynamic range.

III. SUMMARY

Initial work has been done in a study of recombination radiation in gallium arsenide and possibly other intermetallic compounds. A preliminary literature

* Infrared Information Symposium, sponsored by the Office of Naval Research, Pasadena, California

search has been made into the thermal characteristics of gallium arsenide junction diodes in terms of the applicability of the phenomena as the basis for a refrigeration device. Work has also been done on the development of diode fabrication capability involving such functions as dicing, diffusion, and materials evaluation.

The development of a capability for the measurement and evaluation of infrared image tube characteristics is nearing completion. This capability will permit work to proceed on the evaluation and standardization of suitable standards for the performance characterization of infrared image tubes. This work is being done in cooperation with the IRIS Specialty Group on Image Sensing Devices. The problem of dynamic range in image tubes has received special attention.

REFERENCES

1. "Recombination Radiation Emitted by Gallium Arsenide", Proc. of the IRE, 1962 (1822).